Application
for
United States Letters Patent

To all whom it may concern:

Be it known that **David M. Stern, et al.**

have invented certain new and useful improvements in

A Method For Inhibiting New Tissue Growth In Blood Vessels In A Patient Subjected To Blood Vessel Injury

of which the following is a full, clear and exact description.

A Method for Inhibiting New Tissue Growth In Blood Vessels In a Patient Subjected to Blood Vessel Injury

Background of the Invention

Throughout this application, various publications are referenced by number. Full citations for these publications may be found listed at the end of the specification immediately preceding the claims. The disclosures of these publications in their entireties are hereby incorporated by reference into this application in order to more fully describe the state of the art as known to those skilled therein as of the date of the invention described and claimed herein.

It is well-established that the incidence of diabetes is rising sharply in the Unites States and worldwide. Despite aggressive efforts to optimize and achieve strict control of hyperglycemia in affected subjects, the leading cause of death in patients with diabetes remains coronary artery disease (70% of all case fatalities).

In persons with coronary artery stenosis, one form of therapeutic intervention involves percutaneous revascularization (angioplasty) (PTCA). Prior registry data demonstrated that between 15-25% of patients undergoing PTCA have a history of diabetes mellitus. Although there have been great strides in the field of cardiovascular medicine in the last 15 years, there has been little done to improve the outcomes of persons with diabetes and atherosclerotic coronary artery disease. This was most recently clearly demonstrated in a number of recent studies (1-3), including

the BARI investigations and the studies comparing the NHANES I and NHANES II cohorts. Comparing these two epidemiologic surveys, investigators showed a marked improvement in cardiovascular and rated outcomes for patients without a history of diabetes. There was an overall 21.1% and 12.6% risk reduction in all cause mortality in non-diabetic men and women, respectively. In contradistinction, there was only a 1.2% reduction in all cause mortality for diabetic men, and a surprising 15.2% increase in all cause mortality for diabetic women. Similar to the NHANE epidemiologic surveys, patients with diabetes seem to be a higher risk cohort of patients following PTCA interventions. Another example of the heightened risk of vascular disease in diabetes of medical urgency concerns the response to angioplasty as illustrated by the BARI study in which patients with diabetes displayed poorer results from angioplasty than from bypass surgery largely because of accelerated restenosis. From the results of these studies, the view has emerged that diabetic patients are at a heightened risk for angiographic and clinical restenosis, late myocardial infarction, late mortality, and need for future revascularization procedures. In data retrieved from one of our institutes (Mid America Heart Institute) involving over 25,000 patients, we found that diabetic patients have a nearly two-fold increase in in-hospital mortality following both elective and urgent PTCA interventions. The in-hospital mortality rate was 0.8% compared with 1.4% for non-diabetic and diabetic patients undergoing elective PTCA, respectively; $p<0.001$. Similarly, the in-hospital morality rate was 6.9% compared with 12.7% for non-diabetic and diabetic patients undergoing PTCA for acute myocardial infarction, $p<0.001$.

Summary of the Invention

This invention provides for a method for inhibiting new tissue growth in blood vessels in a subject, wherein the subject experienced blood vessel injury, which comprises administering to the subject a pharmaceutically effective amount of an inhibitor of receptor for advanced glycation endproduct (RAGE) so as to inhibit new tissue growth in the subject's blood vessels.

The invention also provides for method for inhibiting neointimal formation in blood vessels in a subject, wherein the subject experienced blood vessel injury, which comprises administering to the subject a pharmaceutically effective amount of an inhibitor of receptor for advanced glycation endproduct (RAGE) so as to inhibit neointimal formation in the subject's blood vessels.

The invention also provides a method for preventing exaggerated restenosis in a diabetic subject which comprises administering to the subject a pharmaceutically effective amount of an inhibitor of receptor for advanced glycation endproduct (RAGE) so as to prevent exaggerated restenosis in the subject.

Brief Description of the Figures

Figure 1. Blockade, using soluble (s) RAGE, suppresses neointimal expansion after carotid artery injury. Fatty Zucker rats were subjected to carotid artery injury as described herein. Rats received either sRAGE or vehicle, albumin, one day prior to injury, and the subsequent 6 days after injury. Rats were sacrificed on day 21 after injury and histologic analysis performed for assessment of neointimal area. Results are reported in mm^2.

Figure 2. Blockade of RAGE, using sRAGE, results in decreased neointima/media ratio after carotid artery injury. Fatty Zucker rats were subjected to carotid artery injury as described above. Rats received either sRAGE or vehicle, albumin, one day prior to injury, and the subsequent 6 days after injury. Rats were sacrificed on day 21 after injury and histologic analysis performed for assessment of neointimal and medial area. Results are reported as the ratio of the neointimal to medial ration.

Detailed Description of the Invention

This invention provides for a method for inhibiting new tissue growth in blood vessels in a subject, wherein the subject experienced blood vessel injury, which comprises administering to the subject a pharmaceutically effective amount of an inhibitor of receptor for advanced glycation endproduct (RAGE) so as to inhibit new tissue growth in the subject's blood vessels.

The invention also provides for method for inhibiting neointimal formation in blood vessels in a subject, wherein the subject experienced blood vessel injury, which comprises administering to the subject a pharmaceutically effective amount of an inhibitor of receptor for advanced glycation endproduct (RAGE) so as to inhibit neointimal formation in the subject's blood vessels.

The invention also provides a method for preventing exaggerated restenosis in a diabetic subject which comprises administering to the subject a pharmaceutically effective amount of an inhibitor of receptor for advanced glycation endproduct (RAGE) so as to prevent exaggerated restenosis in the subject.

In one embodiment of the invention, the subject is a non-human animal, a transgenic non-human animal or a human.

In another embodiment of the invention, the subject has undergone an angioplasty procedure or has undergone surgery to implant a stent in a blood vessel.

In another embodiment of the invention, the inhibitor is a

molecule having a molecular weight from about 500 daltons to about 100 kilodaltons. In another embodiment of the invention, the inhibitor is an organic molecule or an inorganic molecule. In another embodiment of the invention, the inhibitor is a polypeptide or a nucleic acid molecule. In another embodiment of the invention, the inhibitor is soluble receptor for advanced glycation endproduct.

In another embodiment of the invention, the inhibitor is an antibody which specifically binds to receptor for advanced glycation endproduct.

In one embodiment of the invention, the inhibitor is administered to the subject by bolus injection, intraperitoneal injection, i.v., oral administration, topical application to the blood vessel, coating of a device to be placed within the subject, coating of an instrument used during a procedure upon the subject which results in blood vessel injury, or contacting blood of the subject during extracorporeal circulation.

In another embodiment of the invention, the device to be placed within the subject is a stent or an angioplasty balloon.

In another embodiment of the invention, the inhibitor is administered to the subject at a rate from about 2 μg/kg/hr to about 100 μg/kg/hr.

In another embodiment of the invention, the inhibitor is coated onto a stent used during an angioplasty of the subject.

In another embodiment of the invention, the subject is suffering from diabetes, acute thrombotic stroke, venous thrombosis, myocardial infarction, unstable angina, abrupt closure following angioplasty or stent placement, or thrombosis as a result of peripheral vascular surgery.

In another embodiment of the invention, the administering is carried out via injection, oral administration, topical administration, adenovirus infection, liposome-mediated transfer, intravenous administration, intraperitoneal injection, bolus injection, topical application to the blood vessel cells of the subject, or microinjection.

The present invention also provides for a method for determining whether a compound inhibits new tissue growth in a blood vessel in a subject, wherein the blood vessel has been subjected to injury, which comprises: (a) administering the compound to a non-human animal which has undergone blood vessel injury; (b) determining whether the non-human animal has inhibited new tissue growth or inhibited neointimal formation in said blood vessel when compared to new tissue growth or neointimal formation in an injured blood vessel in an identical non-human animal which was not administered the test compound; wherein a decrease in new tissue growth or a decrease in neointimal formation in the non-human animal to which the compound was administered indicates that the test compound inhibits new tissue growth or neointimal formation in the injured blood vessel in the subject.

In one embodiment of the invention, the compound is an organic molecule or an inorganic molecule. In another embodiment of the invention, the compound is a polypeptide or a nucleic acid molecule. In another embodiment of the

invention, the compound is soluble receptor for advanced glycation endproduct. In another embodiment of the invention, the compound is an antibody which specifically binds to receptor for advanced glycation endproduct.

In one embodiment of the invention, the non-human animal is a pig, a bovine, a canine, a rat, a mouse, a sheep or a primate. In another embodiment of the invention, the non-human animal is a non-human diabetic animal model. In another embodiment of the invention, the non-human animal is a Zucker fatty rat.

In one embodiment of the invention, the subject is a human.

In one embodiment of the invention, the inhibitor is a molecule having a molecular weight from about 500 daltons to about 100 kilodaltons. In another embodiment of the invention, the inhibitor is an organic molecule or an inorganic molecule. In another embodiment of the invention, the inhibitor is a polypeptide or a nucleic acid molecule. In another embodiment of the invention, the inhibitor is soluble receptor for advanced glycation endproduct. In another embodiment of the invention, the inhibitor is an antibody which specifically binds to receptor for advanced glycation endproduct.

In one embodiment of the invention, the inhibitor of receptor for advanced glycation endproduct (RAGE) is soluble receptor for advanced glycation endproduct (RAGE).

The present invention provides for a method for determining whether a compound inhibits new tissue growth in a blood vessel in a subject, wherein the blood vessel has been

subjected to injury, which comprises: (a) administering the compound to a non-human animal which has undergone blood vessel injury (e.g., has undergone a stent implant or an angioplasty); (b) determining whether the non-human animal has inhibited new tissue growth or inhibited neointimal formation in said blood vessel when compared to new tissue growth or neointimal formation in an injured blood vessel in an identical non-human animal which was not administered the test compound; wherein a decrease in new tissue growth or a decrease in neointimal formation in the non-human animal to which the compound was administered indicates that the test compound inhibits new tissue growth or neointimal formation in the injured blood vessel in the subject.

In one embodiment of the invention, the blood vessel of the subject is a macrovascular structure. For example, the blood vessel is the aorta, the carotid artery, or a femoral artery or vein.

In one embodiment of the invention, the compound is a molecule having a molecular weight from about 500 daltons to about 100 kilodaltons. In one embodiment of the invention, the compound is an organic molecule or an inorganic molecule. In one embodiment of the invention, the compound is a polypeptide or a nucleic acid molecule.

In one embodiment of the invention, the inhibitor of RAGE is soluble RAGE.

Definitions

As used herein, "treating" encompasses management and care of a patient for the purpose of combating the disease,

condition, or disorder and includes the administration of a compound of the present invention to prevent the onset of the symptoms or complications, alleviating the symptoms or complications, or eliminating the disease, condition, or disorder.

As used herein, "neointimal formation" encompasses new tissue growth in a blood vessel.

"DNA sequence" is a linear sequence comprised of any combination of the four DNA monomers, i.e., nucleotides of adenine, guanine, cytosine and thymine, which codes for genetic information, such as a code for an amino acid, a promoter, a control or a gene product. A specific DNA sequence is one which has a known specific function, e.g., codes for a particular polypeptide, a particular genetic trait or affects the expression of a particular phenotype.

"Genotype" is the genetic constitution of an organism.

"Phenotype" is a collection of morphological, physiological and biochemical traits possessed by a cell or organism that results from the interaction of the genotype and the environment.

"Phenotypic expression" is the expression of the code of a DNA sequence or sequences which results in the production of a product, e.g., a polypeptide or protein, or alters the expression of the zygote's or the organisms natural phenotype.

In another embodiment, the administering is carried out via injection, oral administration, topical administration,

adenovirus infection, liposome-mediated transfer, topical application to the cells of the subject, or microinjection.

In the practice of any of the methods of the invention or preparation of any of the pharmaceutical compositions an "therapeutically effective amount" is an amount which is capable of alleviating the symptoms of the disorder of memory or learning in the subject. Accordingly, the effective amount will vary with the subject being treated, as well as the condition to be treated. For the purposes of this invention, the methods of administration are to include, but are not limited to, administration cutaneously, subcutaneously, intravenously, parenterally, orally, topically, or by aerosol.

The "non-human animals" of the invention include vertebrates such as rodents, non-human primates, sheep, dog, cow, amphibians, reptiles, etc. Preferred non-human animals are selected from the rodent family including rat and mouse, most preferably mouse.

U.S. Patent No. 5,879,380, issued March 9, 1999 to Kalmann, et al., entitled "Assembly for treating blood vessels and a method therefor" is incorporated herein by reference. This patent describes some procedures which are undertaken to treat stenosis in patients and which lead to blood vessel injury.

U.S. Patent No. 5,843,102, issued December 1, 1998, to Kalmann, et al., entitled "Instrument for loosening and cutting through the intima of a blood vessel, and a method therefor" is incorporated herein by reference. This patent describes some procedures which are undertaken to treat

stenosis in patients and which lead to blood vessel injury.

U.S. Patent No. 5,591,225, issued January 7, 1997 to Okuda, entitled "Composite artificial blood vessel" is hereby incorporated herein by reference. This patent describes an artificial blood vessel which could be coated or implanted with the inhibitors described herein in order to carry out the methods for inhibiting neointimal formation in an injured blood vessel of a subject.

The present invention provides a method of treatment for patients undergoing a procedure which causes tissue injury to the patients' blood vessels (e.e.g, angioplasty or stent placement). Said treatment is a therapy comprising administration of an inhibitor of RAGE, wherein the inhibitor inhibits the binding of RAGE to its ligand. It is known that RAGE binds to several ligands, such as AGEs and certain proteins which are family members of the S100/calgranulin family (e.g. EN-RAGE, S100B).

In one embodiment, the subject is suffering from diabetes, acute thrombotic stroke, venous thrombosis, myocardial infarction, unstable angina, abrupt closure following angioplasty or stent placement, or thrombosis as a result of peripheral vascular surgery.

U.S. Patent 6,071,514, issued June 6, 2000 to Grinell, et al., entitled "Methods for treating thrombotic disorders" is is hereby incorporated herein by reference. This patent describes methods for treating thrombotic disorders. It also describes methods of administering compounds to subjects suffering from such disorders.

Nucleotide and Amino Acid sequences of RAGE

The nucleotide and protein (amino acid) sequences for RAGE (both human and murine and bovine) are known. The following references which recite these sequences are incorporated by reference:

Schmidt et al, J. Biol. Chem., 267:14987-97, 1992
Neeper et al, J. Biol. Chem., 267:14998-15004, 1992

RAGE sequences (DNA sequence and translation) from bovine, murine and *homo sapien* are listed hereinbelow. These sequences are available from GenBank as are other sequences of RAGE from other species:

LOCUS BOVRAGE 1426 bp mRNA MAM 09-DEC-1993 DEFINITION Cow receptor for advanced glycosylation end products (RAGE) mRNA, complete cds.
ACCESSION M91212VERSION M91212.1 GI:163650
KEYWORDS RAGE; cell surface receptor.
SOURCE Bos taurus cDNA to mRNA. ORGANISM Bos taurus Eukaryota; Metazoa; Chordata; Craniata; Vertebrata; Euteleostomi; Mammalia; Eutheria; Cetartiodactyla; Ruminantia; Pecora; Bovoidea; Bovidae; Bovinae; Bos.
REFERENCE 1 (bases 1 to 1426) AUTHORS Neeper,M., Schmidt,A.M., Brett,J., Yan,S.D., Wang,F., Pan,Y.C., Elliston,K., Stern,D. and Shaw,A. TITLE Cloning and expression of a cell surface receptor for advanced glycosylation end products of proteins
JOURNAL J. Biol. Chem. 267, 14998-15004 (1992)
MEDLINE 92340547 REFERENCE 2 (bases 1 to 1426) AUTHORS Shaw,A. TITLE Direct Submission JOURNAL Submitted (15-APR-1992) A. Shaw, Department of Cellular and Molecular Biology,

Merck Sharp and Dohme Research Laboratories, West Point, PA 19486

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LOCUS HUMRAGE 1391 bp mRNA PRI 09-DEC-1993

DEFINITION Human receptor for advanced glycosylation end products (RAGE) mRNA, partial cds.

ACCESSION M91211VERSION M91211.1 GI:190845

KEYWORDS RAGE; cell surface receptor.

SOURCE Homo sapiens cDNA to mRNA.

ORGANISM Homo sapiens Eukaryota; Metazoa; Chordata; Craniata; Vertebrata; Euteleostomi; Mammalia; Eutheria; Primates; Catarrhini; Hominidae; Homo.

REFERENCE 1 (bases 1 to 1391)

AUTHORS Neeper,M., Schmidt,A.M., Brett,J., Yan,S.D., Wang,F., Pan,Y.C., Elliston,K., Stern,D. and Shaw,A.

TITLE Cloning and expression of a cell surface receptor for advanced glycosylation end products of proteins
JOURNAL J. Biol. Chem. 267, 14998-15004 (1992)
MEDLINE 92340547
REFERENCE 2 (bases 1 to 1391)
AUTHORS Shaw,A.
TITLE Direct Submission
JOURNAL Submitted (15-APR-1992) A. Shaw, Department of Cellular and Molecular Biology, Merck Sharp and Dohme Research Laboratories, West Point, PA 19486 USA
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LOCUS MUSRECEP 1348 bp mRNA ROD 23-AUG-1994

DEFINITION Mouse receptor for advanced glycosylation end products (RAGE) gene, complete cds.

ACCESSION L33412VERSION L33412.1 GI:532208

KEYWORDS receptor for advanced glycosylation end products.

SOURCE Mus musculus (strain BALB/c, sub_species domesticus) (library: lambda gt10) male adult lung cDNA to mRNA.

ORGANISM Mus musculus Eukaryota; Metazoa; Chordata; Craniata; Vertebrata; Euteleostomi; Mammalia; Eutheria; Rodentia; Sciurognathi; Muridae; Murinae; Mus.

REFERENCE 1 (bases 1 to 1348)

AUTHORS Lundh,E.R., Morser,J., McClary,J. and Nagashima,M.

TITLE Isolation and characterization of cDNA encoding the murine and rat homologues of the mammalian receptor for advanced glycosylation end products

JOURNAL UnpublishedCOMMENT On Aug 24, 1994 this sequence version replaced

gi:496146.

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961 tcacagaaac cggcgatgag gggccagctg aaggctctgt gggtgagtct gggctgggta
1021 cgctagccct ggccttgggg atcctgggag gcctgggagt agtagccctg ctcgtcgggg
1081 ctatcctgtg gcgaaaacga caacccaggc gtgaggagag gaaggccccg gaaagccagg
1141 aggatgagga ggaacgtgca gagctgaatc agtcagagga agcggagatg ccagagaatg
1201 gtgccggggg accgtaagag cacccagatc gagcctgtgt gatggcccta gagcagctcc
1261 cccacattcc atcccaattc ctccttgagg cacttccttc tccaaccaga gcccacatga
1321 tccatgctga gtaaacattt gatacggc// **(SEQ ID NO:6)**

Inhibitors of RAGE:

Inhibitors of RAGE include any molecule which, when introduced into a cell or a subject, is capable of inhibiting the biological activity of RAGE. For example, one such inhibitor would be able to inhibit the activity of RAGE as described: the binding of RAGE to AGEs in the blood or the binding of RAGE to its ligands, for example, EN-RAGE, S100B, or a member of the S100/calgranulin protein family). The S100/calgranulin protein family are characterized by containing EF hand loops and have been shown to bind RAGE.

Examples of an inhibitor of RAGE activity are soluble RAGE, an antibody which specifically binds to RAGE, a truncated version of RAGE which is capable of acting as a competitive inhibitor of RAGE. A fragment of RAGE which includes the amyloid beta peptide binding portion of RAGE and introduced into the cell or subject as a soluble polypeptide. Other types of inhibitors would be known to one of skill in the

art. For example, a small molecule could be prepared which mimics the amyloid beta peptide binding region of RAGE and administered alone as an inhibitor.

Pharmaceutical compositions and Carriers

As used herein, the term "suitable pharmaceutically acceptable carrier" encompasses any of the standard pharmaceutically accepted carriers, such as phosphate buffered saline solution, water, emulsions such as an oil/water emulsion or a triglyceride emulsion, various types of wetting agents, tablets, coated tablets and capsules. An example of an acceptable triglyceride emulsion useful in intravenous and intraperitoneal administration of the compounds is the triglyceride emulsion commercially known as Intralipid®.

Typically such carriers contain excipients such as starch, milk, sugar, certain types of clay, gelatin, stearic acid, talc, vegetable fats or oils, gums, glycols, or other known excipients. Such carriers may also include flavor and color additives or other ingredients.

This invention also provides for pharmaceutical compositions including therapeutically effective amounts of protein compositions and compounds together with suitable diluents, preservatives, solubilizers, emulsifiers, adjuvants and/or carriers useful in treatment of neuronal degradation due to aging, a learning disability, or a neurological disorder. Such compositions are liquids or lyophilized or otherwise dried formulations and include diluents of various buffer content (e.g., Tris-HCl., acetate, phosphate), pH and ionic strength, additives such as albumin or gelatin to prevent

absorption to surfaces, detergents (e.g., Tween 20, Tween 80, Pluronic F68, bile acid salts), solubilizing agents (e.g., glycerol, polyethylene glycerol), anti-oxidants (e.g., ascorbic acid, sodium metabisulfite), preservatives (e.g., Thimerosal, benzyl alcohol, parabens), bulking substances or tonicity modifiers (e.g., lactose, mannitol), covalent attachment of polymers such as polyethylene glycol to the compound, complexation with metal ions, or incorporation of the compound into or onto particulate preparations of polymeric compounds such as polylactic acid, polglycolic acid, hydrogels, etc, or onto liposomes, micro emulsions, micelles, unilamellar or multi lamellar vesicles, erythrocyte ghosts, or spheroplasts. Such compositions will influence the physical state, solubility, stability, rate of in vivo release, and rate of in vivo clearance of the compound or composition. The choice of compositions will depend on the physical and chemical properties of the compound.

Controlled or sustained release compositions include formulation in lipophilic depots (e.g., fatty acids, waxes, oils). Also comprehended by the invention are particulate compositions coated with polymers (e.g., poloxamers or poloxamines) and the compound coupled to antibodies directed against tissue-specific receptors, ligands or antigens or coupled to ligands of tissue-specific receptors. Other embodiments of the compositions of the invention incorporate particulate forms protective coatings, protease inhibitors or permeation enhancers for various routes of administration, including parenteral, pulmonary, nasal and oral.

Portions of the compound of the invention may be "labeled" by association with a detectable marker substance (e.g., radiolabeled with ^{125}I or biotinylated) to provide reagents

useful in detection and quantification of compound or its receptor bearing cells or its derivatives in solid tissue and fluid samples such as blood, cerebral spinal fluid or urine.

When administered, compounds are often cleared rapidly from the circulation and may therefore elicit relatively short-lived pharmacological activity. Consequently, frequent injections of relatively large doses of bioactive compounds may by required to sustain therapeutic efficacy. Compounds modified by the covalent attachment of water-soluble polymers such as polyethylene glycol, copolymers of polyethylene glycol and polypropylene glycol, carboxymethyl cellulose, dextran, polyvinyl alcohol, polyvinylpyrrolidone or polyproline are known to exhibit substantially longer half-lives in blood following intravenous injection than do the corresponding unmodified compounds (Abuchowski et al., 1981; Newmark et al., 1982; and Katre et al., 1987). Such modifications may also increase the compound's solubility in aqueous solution, eliminate aggregation, enhance the physical and chemical stability of the compound, and greatly reduce the immunogenicity and reactivity of the compound. As a result, the desired *in vivo* biological activity may be achieved by the administration of such polymer-compound adducts less frequently or in lower doses than with the unmodified compound.

Attachment of polyethylene glycol (PEG) to compounds is particularly useful because PEG has very low toxicity in mammals (Carpenter et al., 1971). For example, a PEG adduct of adenosine deaminase was approved in the United States for use in humans for the treatment of severe combined immunodeficiency syndrome. A second advantage afforded by the conjugation of PEG is that of effectively reducing the

immunogenicity and antigenicity of heterologous compounds. For example, a PEG adduct of a human protein might be useful for the treatment of disease in other mammalian species without the risk of triggering a severe immune response. The compound of the present invention capable of alleviating symptoms of a cognitive disorder of memory or learning may be delivered in a microencapsulation device so as to reduce or prevent an host immune response against the compound or against cells which may produce the compound. The compound of the present invention may also be delivered microencapsulated in a membrane, such as a liposome.

Polymers such as PEG may be conveniently attached to one or more reactive amino acid residues in a protein such as the alpha-amino group of the amino terminal amino acid, the epsilon amino groups of lysine side chains, the sulfhydryl groups of cysteine side chains, the carboxyl groups of aspartyl and glutamyl side chains, the alpha-carboxyl group of the carboxy-terminal amino acid, tyrosine side chains, or to activated derivatives of glycosyl chains attached to certain asparagine, serine or threonine residues.

Numerous activated forms of PEG suitable for direct reaction with proteins have been described. Useful PEG reagents for reaction with protein amino groups include active esters of carboxylic acid or carbonate derivatives, particularly those in which the leaving groups are N-hydroxysuccinimide, p-nitrophenol, imidazole or 1-hydroxy-2-nitrobenzene-4-sulfonate. PEG derivatives containing maleimido or haloacetyl groups are useful reagents for the modification of protein free sulfhydryl groups. Likewise, PEG reagents containing amino hydrazine or hydrazide groups are useful for reaction with aldehydes generated by periodate oxidation of

carbohydrate groups in proteins.

In one embodiment the compound of the present invention is associated with a pharmaceutical carrier which includes a pharmaceutical composition. The pharmaceutical carrier may be a liquid and the pharmaceutical composition would be in the form of a solution. In another embodiment, the pharmaceutically acceptable carrier is a solid and the composition is in the form of a powder or tablet. In a further embodiment, the pharmaceutical carrier is a gel and the composition is in the form of a suppository or cream. In a further embodiment the active ingredient may be formulated as a part of a pharmaceutically acceptable transdermal patch.

The following U.S. Patents are hereby incorporated by reference:

PAT. NO.	Title
6,120,533	Stent delivery system for a radioisotope stent
6,093,141	Stereotactic radiotreatment and prevention
6,080,190	Intraluminal stent
6,077,273	Catheter support for stent delivery
6,074,362	Catheter system having imaging, balloon angioplasty, and stent deployment capabilities, and methods of use for guided stent deployment
6,071,514	Methods for treating thrombotic disorders
6,071,286	Combination angioplasty balloon/stent deployment device
6,059,809	Protective angioplasty device
6,053,913	Rapid exchange stented balloon catheter having ablation capabilities
6,027,509	Stent retrieval device

6,027,508 Stent retrieval device

6,015,430 Expandable stent having a fabric liner

6,011,995 Endovascular device for hyperthermia and angioplasty and method for using the same

6,004,339 Balloon catheter with multiple distensibilities

5,980,485 Pressure-sensitive balloon catheter

5,976,153 Stent delivery catheter system

5,957,971 Intraluminal stent

5,944,735 Process for stent compression

5,910,145 Stent delivery catheter system

5,902,299 Cryotherapy method for reducing tissue injury after balloon angioplasty or stent implantation

5,893,867 Stent positioning apparatus and method

5,893,840 Releasable microcapsules on balloon catheters

5,891,133 Apparatus for laser-assisted intra-coronary transmyocardial revascularization and other applications

5,871,437 Radioactive stent for treating blood vessels to prevent restenosis

5,868,755 Sheath retractor mechanism and method

5,855,563 Method and apparatus for sequentially performing multiple intraluminal procedures

5,854,223 S-DC28 as an antirestenosis agent after balloon injury

5,849,034 Intraluminal stent

5,843,163 Expandable stent having radioactive treatment means

5,836,952 Hand-held stent crimper

5,833,982 Modified factor VII

5,814,061 Rapid exchange stent delivery balloon catheter

5,800,507 Intraluminal stent

5,799,384 Intravascular radially expandable stent

5,797,887 Medical device with a surface adapted for exposure

to a blood stream which is coated with a polymer containing a nitrosyl-containing organo-metallic compound which releases nitric oxide from the coating to mediate platelet aggregation

5,792,144 Stent delivery catheter system

5,776,141 Method and apparatus for intraluminal prosthesis delivery

5,766,192 Atherectomy, angioplasty and stent method and apparatus

5,755,776 Permanent expandable intraluminal tubular stent

5,749,848 Catheter system having imaging, balloon angioplasty, and stent deployment capabilities, and method of use for guided stent deployment

5,749,825 Means method for treatment of stenosed arterial bifurcations

5,746,766 Surgical stent

5,746,764 Stent compression instrument

5,743,874 Integrated catheter for balloon angioplasty and stent delivery

5,738,674 Stent loading mechanism

5,730,698 Balloon expandable temporary radioisotope stent system

5,722,979 Pressure assisted ultrasonic balloon catheter and method of using same

5,702,419 Expandable, intraluminal stents

5,690,642 Rapid exchange stent delivery balloon catheter

5,669,932 Means for accurately positioning an expandable stent

The disclosures of publications referenced in this application in their entireties are hereby incorporated by reference into this application in order to more fully

describe the state of the art as known to those skilled therein as of the date of the invention described and claimed herein.

This invention is illustrated in the Experimental Details section which follows. These sections are set forth to aid in an understanding of the invention but are not intended to, and should not be construed to, limit in any way the invention as set forth in the claims which follow thereafter.

EXPERIMENTAL DETAILS

Example 1: Blockade of Receptor for Age (Rage) Suppresses Neointimal Formation in Diabetic Rats Subjected to Carotid Artery Injury

It is well-established that the incidence of diabetes is rising sharply in the Unites States and worldwide. Despite aggressive efforts to optimize and achieve strict control of hyperglycemia in affected subjects, the leading cause of death in patients with diabetes remains coronary artery disease (70% of all case fatalities). In persons with coronary artery stenosis, one form of therapeutic intervention involves percutaneous revascularization (angioplasty) (PTCA). Prior registry data demonstrated that between 15-25% of patients undergoing PTCA have a history of diabetes mellitus.

Although there have been great strides in the field of cardiovascular medicine in the last 15 years, there has been little done to improve the outcomes of persons with diabetes and atherosclerotic coronary artery disease. This was most recently clearly demonstrated in a number of recent studies (1-3), including the BARI investigations and the studies comparing the NHANES I and NHANES II cohorts. Comparing these two epidemiologic surveys, investigators showed a marked improvement in cardiovascular and rated outcomes for patients without a history of diabetes. There was an overall 21.1% and 12.6% risk reduction in all cause mortality in non-diabetic men and women, respectively. In contradistinction, there was only a 1.2% reduction in all cause mortality for diabetic men, and a surprising 15.2% increase in all cause mortality for diabetic women. Similar

to the NHANE epidemiologic surveys, patients with diabetes seem to be a higher risk cohort of patients following PTCA interventions.

Another example of the heightened risk of vascular disease in diabetes of medical urgency concerns the response to angioplasty as illustrated by the BARI study in which patients with diabetes displayed poorer results from angioplasty than from bypass surgery largely because of accelerated restenosis. From the results of these studies, the view has emerged that diabetic patients are at a heightened risk for angiographic and clinical restenosis, late myocardial infarction, late mortality, and need for future revascularization procedures.

In data retrieved from one of our institutes (Mid America Heart Institute) involving over 25,000 patients, we found that diabetic patients have a nearly two-fold increase in in-hospital mortality following both elective and urgent PTCA interventions. The in-hospital mortality rate was 0.8% compared with 1.4% for non-diabetic and diabetic patients undergoing elective PTCA, respectively; $p<0.001$. Similarly, the in-hospital morality rate was 6.9% compared with 12.7% for non-diabetic and diabetic patients undergoing PTCA for acute myocardial infarction, $p<0.001$.

In order to dissect the contribution of multiple, diabetes-associated factors in the response to arterial injury, we developed a model of exaggerated neointimal formation in rats with type 2 diabetes. We studied the Zucker fatty rat, as this is a model of insulin resistance, hyperglycemia, hyperlipidemia and obesity. This model, in certain respects, at least, typifies the characteristics of

human subjects with type 2 diabetes. Our studies showed that upon induction of balloon injury in the carotid arteries of these rats, compared with lean, non-hyperglycemic control rats, an nearly two-fold increase in neointimal area after balloon injury resulted. This rat model therefore provided a means to dissect the contributory factors involved in diabetic complications.

In this context, the accumulation of late-stage glycoxidation adducts of proteins, termed AGEs (Advanced Glycoxidation Endproducts), in diabetic tissues occurs at an accelerated rate due to increased levels of glucose, superimposed oxidant stress, and a chronic inflammatory component evident in macrovascular atherosclerotic, and restenotic vascular lesions. AGEs modify long-lived molecules in the blood vessel wall considerably before symptomatic atherosclerosis occurs, and exert their cellular effects in large part via engagement of RAGE (Receptor for AGEs) (4-5). RAGE is the only well-characterized signal transduction receptor which, on binding AGE ligands, activates intracellular pathways leading to chronic cellular perturbation in cells of the atherosclerotic vessel wall, including endothelium, mononuclear phagocytes, lymphocytes and smooth muscle cells (6).

Furthermore, RAGE also serves as a receptor for a family of inflammatory mediators, S100/calgranulin polypeptides, such as EN-RAGE (7), which coexist with AGEs at the site of atherosclerotic lesions and provide another ligand to reinforce sustained cellular stimulation mediated by RAGE. As we speculated that these findings are relevant to aggressive restenosis accompanying angioplasty in patients with diabetes, reflecting an underlying accelerated

atherosclerotic process due, probably in large part, to smooth muscle cell migration, matrix production and proliferation, we tested these concepts in a rat model of exaggerated neointimal expansion after balloon injury to the carotid artery.

In previous studies, we found that blockade of RAGE, using soluble (s) RAGE (the extracelluar ligand binding domain of the receptor), suppressed the development of accelerated atherosclerosis in apolipoprotein E null mice (8). It was thus logical to administer sRAGE to fatty Zucker rats and test the hypothesis that suppression of expanded neointimal formation might ensue.

MATERIALS AND METHODS

Induction of carotid artery balloon injury. Carotid arterial injury was induced in Fatty Zucker rats with a 2 French Fogarty balloon catheter (Baxter Health Care Corp., Santa Ana, CA). Certain rats, as detailed below, received murine soluble RAGE, 0.5 mg, the day prior to surgery, and then once daily for a total of 6 more days (total treatment; 7 days). The remaining rats received murine serum albumin, 0.5mg/day as control. Injections were given by intraperitoneal route, in sterile-endotoxin-free phosphate-buffed saline. All Zucker fatty rats were sacrificed on day 21 following carotid arterial injury.

Upon induction of anesthesia, a midline abdominal incision was made and an 18-gauge intravenous catheter was introduced to the aortic bifurcation and the distal abdominal aorta was exposed. The aorta was flushed with 50 ml of Ringer's lactate solution at 120 mm Hg followed by in vivo fixation

with 200ml of 5% Histochoice infused over five minutes at 120mm Hg. Once the infusion was begun in all animals, they were sacrificed with an overdose of Pentothal through the tail vein.

After five minutes of perfusion fixation, the entire right and left carotid arteries were embedded in paraffin and sectioned at 5 mm sections from the proximal to the distal end. Histologic morphometric and immunohistochemical studies were done utilizing these day 21 paraffin-embedded sections.

Treatment. Thirteen Zucker fatty rats were randomly assigned to treatment with sRAGE (n=7) or murine serum albumin (MSA) (n=6).

Analysis of lesions. Slides obtained from paraffin-embedded sections were stained with hematoxylin and eosin (H&E) and elastic van Giessen stains. Morphometric analysis of the arterial segments was carried out by an observer blinded to the treatment groups. The investigator utilized a computerized digital microscopic telemetry algorithm (NIH Image 1.56). The cross- sectional areas of the lumen, intima, media and the visceral area as circumscribed the external elastic lamina were determined. Analysis was performed using sections stained with H&E under 40x microscopic magnification.

RESULTS

The key index of an exaggerated response to arterial injury is the extent of neointimal formation. In fatty Zucker rats treated with sRAGE, there was a significant reduction in neointimal area compared with MSA-treated animals (0.8 mm^2

compared with 0.15 mm^2, respectively; p=0.001) (**Fig. 1**). Consistent with this observation, the neointimal to media ration for sRAGE-treated Zucker fatty rats was 0.83, compared to 1.43 mm^2 in rats teated with MSA; p=0.005 (**Fig. 2**).

Preliminary studies have been performed to determine the mechanism underlying the beneficial effects of sRAGE. Rats undergoing balloon injury were treated with sRAGE or MSA. Prior to sacrifice, rats were treated with multiple intraperitoneal injections of bromodeoxyrudine (BrdU). On day 5 after balloon injury, our preliminary studies have shown a reduction in smooth muscle proliferation and migration, as evidenced by the amount of BrdU positive cells staining in the media and intima in rats treated with sRAGE vs MSA (18% vs 25.4% Brdu-positive cells, respectively). We are now in the process of expanding the numbers of animals to be included in these mechanistic studies, and in testing the effects of sRAGE on various days after injury.

DISCUSSION

One consequence of the endogenous development of accelerated atherosclerosis in subjects with diabetes is the need for revascularization in order to ensure adequate coronary flow and to minimize ischemic episodes. In such cases, one course of therapy includes the exogenousintroduction of balloon catheter devices to disrupt intimal vascular lesions, thereby leading to revascularization and enhanced blood flow. In the case of subjects with diabetes, the response to percutaneous balloon catheter mediated revascularization is often untoward, with excessive formation of neointima, itself a risk for further ischemic episodes or infarction. Here we have shown the first time the blockade of RAGE, by

administration of soluble RAGE, suppresses exaggerated neointimal expansion. These findings provide a novel means to prevent excessive restenosis in subjects with diabetes.

5

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